National Defense Center for Energy and Environment

Aviation Requirements for Use of Recycled MIL-PRF-680

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Outline

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- Path Forward

Background and Objective

- Army is interested in potential to recycle and reuse spent MIL-PRF-680 Type II for cleaning *Aviation* components
  - Approximately 1,000 gallons of virgin MIL-PRF-680 Type II used and disposed every 6 months at Fort Rucker
    - Calculated using the full capacity of the parts washers
  - Recycling will reduce the need to purchase virgin solvent and reduce disposal costs
  - Expressed interest received from various Army depots and Aviation Center Logistics Commands
- Testing had not been conducted to determine if the recycled solvent is viable for use on Aviation components
  - Recycled solvent is currently used to clean *Ground* Support Equipment parts

Approach

- Tested four Clarus parts washers at Fort Rucker Motor Pool
  - Ground equipment cleaned for 12 months
  - Solvent recycled twice (at 4 and 8 months) using a Clarus Tornado Filtration System
  - Samples taken monthly and after each recycle
    - Quarter-samples taken from each of 4 parts washers
    - Parts washers topped off with virgin solvent

Clarus PCS-25 Parts Washer

Clarus Tornado Filtration System

Approach (cont.)

Test Name	Method Number	Acceptance Criteria	Samples Tested
Flash Point	ASTM D93	61-92°C (141-198°F)	All
Solvent Cleaning Power	MIL-PRF-680B, App. A	85%, minimum	All
Total Chlorine Content	EPA 330.5, MIL-PRF-680B	100 mg/L, maximum	All
Vapor Pressure	ASTM D2879	2.0 mm Hg at 20°C, max	All
Acid Number	ASTM D664	Neutral acidity	All
Base Number	ASTM D2896	None listed	All
Ash Content	ASTM D482	None listed	All
Water Content by Distillation	ASTM D95	None listed	New Solvent, Pre-Recycle, Post-Recycle, Final Sample
Copper Strip Corrosion	ASTM D130	1b, max	New Solvent, Post-Recycle
Sandwich Corrosion	ASTM F1110	Severity rating of “1” on the 0-5 scale (0 = No corrosion)	
Total Immersion Corrosion	ASTM F483	Mg – 0.5 mg/cm^2 avg weight loss, max Al – 0.15 mg/cm^2, max Ti – 0.10 mg/cm^2, max 1020 steel – 0.25 mg/cm^2, max	
Stress-Corrosion of Ti Alloys	ASTM F945	No cracking	

Approach (cont.)

- 15 samples collected in total
  - 1 new solvent (“Month Zero”)
  - 12 monthly (After regular use)
  - 2 immediately after recycle (Months 4 and 8)
- Began official testing November 1, 2010 (new solvent)
  - First recycle conducted in March 2011
  - Second recycle conducted in July 2011
  - Final sample taken in November 2011
- Each sample tested at CTC laboratory in Johnstown, PA

Schedule

Test No.	Month No.	Month*	Condition of MIL-PRF-680 Type II	ASTM D56	MIL-PRF-680 Appendix A	MIL-PRF-680 Section 4.4.4	ASTM D2879	ASTM D664	ASTM D2896	ASTM D482	ASTM D95	ASTM D130	ASTM F1110	ASTM F483	ASTM F945
1	0	Nov. 2010	Virgin	•	•	•	•	•	•	•	•	•	•	•	•
			Solvent Placed into Parts Washers; Cleaning Process Initiated												
2	1	Dec. 2010	Used	•	•	•	•	•	•	•					
3	2	Jan. 2011	Used	•	•	•	•	•	•	•					
4	3	Feb. 2011	Used	•	•	•	•	•	•	•					
5	4	Mar. 2011	Used	•	•	•	•	•	•	•	•				
			End of 4th Month: First Recycling Process Completed												
6	4	Mar. 2011	Recycled	•	•	•	•	•	•	•	•	•	•	•	•
7	5	Apr. 2011	Recycled (Used)	•	•	•	•	•	•	•					
8	6	May 2011	Recycled (Used)	•	•	•	•	•	•	•					
9	7	June 2011	Recycled (Used)	•	•	•	•	•	•	•					
10	8	July 2011	Recycled (Used)	•	•	•	•	•	•	•	•				
			End of 8th Month: Second Recycling Process Completed												
11	8	July 2011	Recycled-Recycled	•	•	•	•	•	•	•	•	•	•	•	•
12	9	Aug. 2011	Recycled-Recycled (Used)	•	•	•	•	•	•	•					
13	10	Sept. 2011	Recycled-Recycled (Used)	•	•	•	•	•	•	•					
14	11	Oct. 2011	Recycled-Recycled (Used)	•	•	•	•	•	•	•					
15	12	Nov. 2011	Recycled-Recycled (Used)	•	•	•	•	•	•	•	•				

*Target date for sample collection will be the first of each month. Adjustments for weekends/holidays will be communicated with Fort Rucker.

Recycling Process

1st Pass

1st Pass

2nd / 3rd Passes

4th Pass

External Container

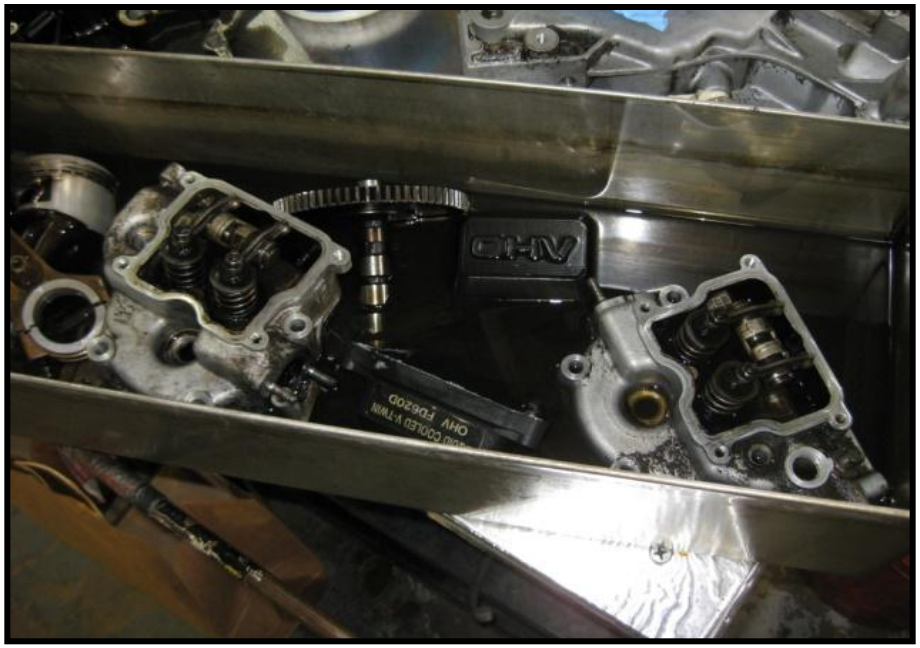
Recycled solvent transferred back to parts washer

Demonstration Results

Initial pass through recycler

After third pass
(15 minutes after initial pass)

Demonstration Results (cont.)



Solvent before recycling

After recycling
(30 minutes later)

Testing Results

Test No.	Month No.	Month	Condition of Solvent	ASTM D56	MIL-PRF-680 App. A	MIL-PRF-680 4.4.4	ASTM D2879	ASTM D664	ASTM D2896	ASTM D482	ASTM D95	ASTM D130	ASTM F1110	ASTM F483	ASTM F945
1	0	Nov. 2010	Virgin	64°C (147°F)	92%	< 0.01 ppm	0.4 mmHg	0.002 mg/g	< 0.01 mg KOH/g	< 0.05% ash	< 0.05%	1b	See table	See table	No cracking
Solvent Placed into Parts Washers; Cleaning Process Initiated															
2	1	Dec. 2010	Used	62°C (144°F)	93%	0.02	2.3	0.01	< 0.01	0.21%					
3	2	Jan. 2011	Used	63°C (145°F)	94%	0.06	1	0.014	0.019	0.08%					
4	3	Feb. 2011	Used	65°C (149°F)	93%	< 0.01	1.3	0.016	< 0.01	0.16%					
5	4	Mar. 2011	Used	64°C (147°F)	95%	0.07	0.6	0.016	< 0.01	0.12%	< 0.05%				
End of 4th Month: First Recycling Process Completed															
6	4	Mar. 2011	Recycled	65°C (149°F)	94%	0.02	0.1	0.016	< 0.01	0.08%	< 0.05%	1a	See table	See table	No cracking
7	5	Apr. 2011	Recycled (Used)	64°C (147°F)	94%	0.03	0.1	0.017	< 0.01	0.06%					
8	6	May-11	Recycled (Used)	63°C (145°F)	93%	< 0.01	0.3	0.022	< 0.01	0.07%					
9	7	Jun-11	Recycled (Used)	63°C (145°F)	95%	0.01	0.4	0.025	0.023	0.08					
10	8	Jul-11	Recycled (Used)	64°C (147°F)	95%	0.02	0.7	0.021	No Result	< 0.05%	< 0.05%				
End of 8th Month: Second Recycling Process Completed															
11	8	Jul-11	Recycled-Recycled	63°C (145°F)	95%	< 0.01	0.5	0.022	< 0.01	< 0.05%	< 0.05%	1a	See table	See table	No cracking
12	9	Aug. 2011	Recycled-Recycled (Used)	63°C (145°F)	100%	< 0.01	0.1	0.044	< 0.01	< 0.05%					
13	10	Sept. 2011	Recycled-Recycled (Used)	62°C (144°F)	99.90%	< 0.01	< 0.01	0.045	0.02	< 0.05%					
14	11	Oct. 2011	Recycled-Recycled (Used)	62°C (144°F)	96.00%	0.01	0.09	0.002	0.019	< 0.05%					
15	12	Nov. 2011	Recycled-Recycled (Used)	63°C (145°F)	95.00%	< 0.01	2.9	< 0.002	0.015	< 0.05%	<0.05%				

Testing Results (cont.)

ASTM F1110 - Sandwich Corrosion

Sample Name	Substrate Material	Corrosion Rating
Month 0 - Virgin Material	2024 T3 Al non-clad panels	Panel #1: 1, Discolored, 5% Corrosion;
		Panel #2: 2, Discolored, 10% Corrosion
	2024-T3 Al clad panels	Panel #1: 2, Discolored, 10% Corrosion
		Panel #2: 1, Discolored
	7075-T6 Al non-clad panels	1, Discolored
	7075-T6 Al clad panels	1, Discolored
Month 4 - Recycled Sample	2024 T3 Al non-clad panels	1, Discolored
	2024-T3 Al clad panels	1, Discolored
	7075-T6 Al non-clad panels	1, Discolored
	7075-T6 Al clad panels	1, Discolored, 5% Corrosion
Month 8 - Recycled-Recycled Sample	2024 T3 Al non-clad panels	Panel #1: 2, Discolored, 10% Corrosion
		Panel #2: 3, Discolored, up to 25% Corrosion
	2024-T3 Al clad panels	Panel #1: 4, Discolored, more than 25% corrosion – pitting
		Panel #2: 3, Discolored, up to 25% corrosion
	7075-T6 Al non-clad panels	1, Discolored
	7075-T6 Al clad panels	1, Discolored

Testing Results (cont.)

ASTM F483 – Total Immersion Corrosion

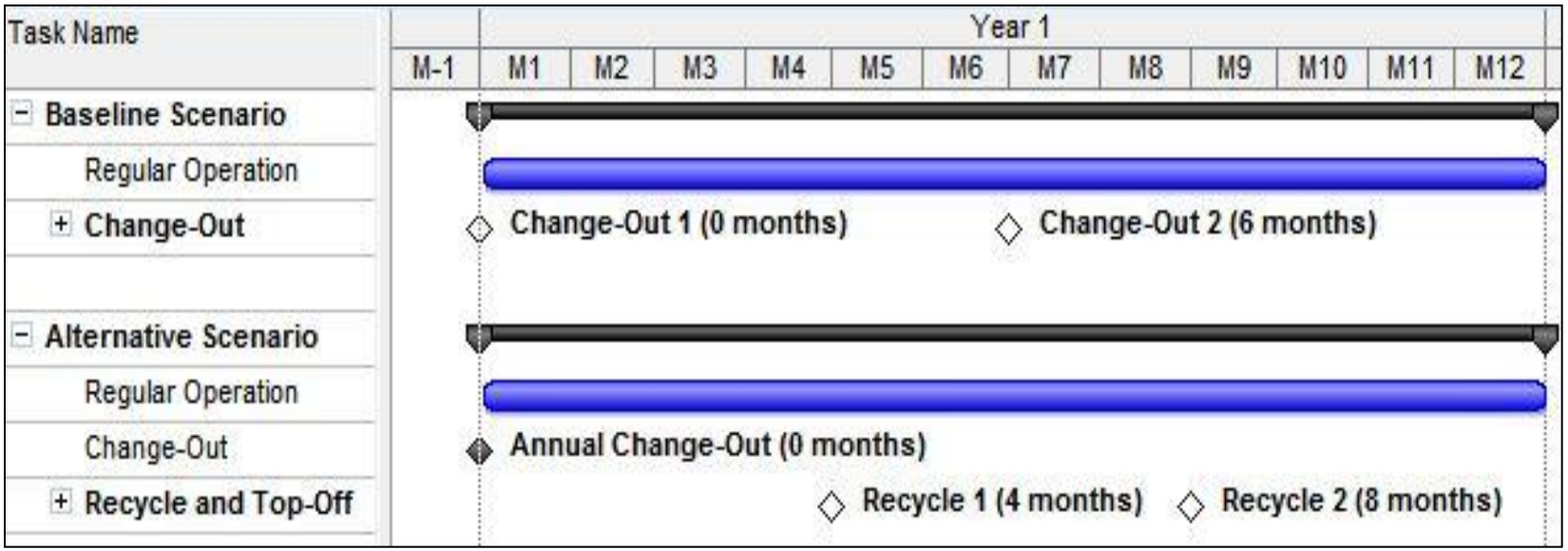
Sample Name	Material	After 24 hours immersion	After 168 hours immersion
Month 0 - Virgin Material	Mg AZ31B Alloy	< 0.1 mg/cm^2	< 0.1 mg/cm^2
	T3 Al Alloy	< 0.1 mg/cm^2	< 0.1 mg/cm^2
	6Al-4V Ti Alloy	< 0.1 mg/cm^2	< 0.1 mg/cm^2
	1020 Steel Alloy	< 0.1 mg/cm^2	< 0.1 mg/cm^2
Month 4 - Recycled Sample	Mg AZ31B Alloy	< 0.1 mg/cm^2	< 0.1 mg/cm^2
	T3 Al Alloy	< 0.1 mg/cm^2	< 0.1 mg/cm^2
	6Al-4V Ti Alloy	< 0.1 mg/cm^2	< 0.1 mg/cm^2
	1020 Steel Alloy	< 0.1 mg/cm^2	< 0.1 mg/cm^2
Month 8 - Recycled-Recycled Sample	Mg AZ31B Alloy	< 0.1 mg/cm^2	< 0.1 mg/cm^2
	T3 Al Alloy	< 0.1 mg/cm^2	< 0.1 mg/cm^2
	6Al-4V Ti Alloy	< 0.1 mg/cm^2	< 0.1 mg/cm^2
	1020 Steel Alloy	< 0.1 mg/cm^2	< 0.1 mg/cm^2; small amount of red rust noted on bottom of panel 2

Testing Results (cont.)

- Recycled degreaser met all of the criteria established for the testing conducted under this program
- Recycling and re-recycling of the solvent degreaser had very little effect on the chemical properties of the degreaser
  - The Aviation Engineering Directorate (AED) reviewed the results and determined the solvent did not pass sandwich corrosion due to pitting.
  - Vapor pressure had two instances of not meeting the specification
- The testing results clearly show that recycling can extend the useful life of the solvent degreaser

Cost Benefit Analysis

- Cost estimated for 43 aviation parts washers at Fort Rucker
- Baseline and Alternative Scenarios
  - Baseline: Continue twice-annual change-out of solvent
  - Alternative: Annual change-out; Recycle at 4 and 8 months



Cost Benefit Analysis (cont.)

- Cost parameters analyzed
  - Labor: for change-out and recycling
  - Materials: solvent procurement
  - Utilities: electric for parts washers and recycler
  - Waste Disposal: hazardous and non-hazardous

Annual Costs	Baseline	Alternative	Savings (Annual)
Labor	$3,727	$7,453	($3,727)
Materials	$30,493	$18,579	$11,914
Utilities	$1,238	$1,240	($2)
Waste Disposal	$2,461	$1,321	$1,140
Total	**$37,919**	**$28,594**	**$9,325**

Clarus Tornado unit retails for $18,530. Not included in CBA.

Path Forward

- **AED has reviewed the results and approved recycled MIL-PRF-680 Type II on aviations components with the following restrictions**
  - Recycled MIL-PRF-680 shall not be used on mixed aluminum components (such as aluminum honeycomb) where sandwich corrosion may occur
  - The useful life of recycled/used MIL-PRF-680 solvent is restricted to12 months
- **Implement at Fort Rucker**
  - Use mobile recycling system in conjunction with 43 aviation parts washers
- **Expand process to facilities outside of Fort Rucker**

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